SYSTEMS DEVELOPMENT
AND
INTEGRATION ENGINEERING

REVIEW DRAFT

15 JUNE 1995

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1. Description

This document describes the general steps in systems development and integration engineering and the considerations involved. The descriptions presented are at a moderate level of detail. Each systems development and integration is unique and any further breakdown of the processes involved will be dependent on the individual effort being examined. An overview of the Systems Development and Integration Process is shown in figure 1, the Process Template.

Preceding Process

Systems Engineering Management

Systems Development & Integration Engineering

Next Process

Multiple Processes

Purpose

To translate a defined need into an operational system that meets balances all requirements including cost, performance, and timeliness.

Critical

Essential to providing quality and cost effective products to customers

Inputs [Suppliers]

TWP/TBS (1.0, 4.0)
SEMP (1.0, 4.1.1)
SEMS/SEDS (1.0, 4.1.1)
User Needs (1.0, 4.1.1)
Measures Of Effectiveness
Environments, Constraints (1.0, 4.10)
Technology Base (4.x)
Systems Engineering Support (4.1.x, 4.x)

Primary sub-processes

Define Potential Materiel Solutions
Develop System Requirements
Develop System Design
Conduct Trades Studies
Assess Preliminary Detail Design
Assess Detail Design
Assess Fabrication
Conduct System Integration
Perform System And Subsystem Verification
Develop Engineering Drawings And Associated Lists/ Specifications
Develop Engineering Instructions
Customer Interface and Feedback

Outputs [Customers]

Candidate System Concepts, Feasibility Assessments [1.0, User]

Functional/Allocated Baselines, Functional Partitions, Interfaces, Decision Database, Measured System TPMs [1.0, 4.1, 4.x, 5.0]

Trade Results, Configuration Recommendations [1.0, 4.1, 4.x]

Technical Reports, Recommended Baseline Changes, SCNs, ECPs [1.0, 4.1, 4.x, 5.0]

Engineering Drawings And Associated Documentation [1.0, 4.x, 5.0, OPTEVFOR, User]

Engineering Instructions [User, 1.0]

Entry Criteria

Initiation of a System Development
Initiation of a System Modification
Implementation of a Plan for a System Development/Modification
Approved MNS, TOR/ORD
Approved Tasking
Specific Criteria Vary By Acquisition Phase

Supporting sub-processes

Engineering Support From Other Disciplines, Especially 4.x.1

Exit Criteria

Cessation or Completion of the System Development
Cessation or Completion of the System Modification
Cessation or Completion of the Plan for a system Development or Modification
Criteria Vary By Acquisition Phase

Agents

System Engineers from 4.1.2 supported by Product Teams from across the Corporation

Tools

TPM Tracking Tools, Reqts Mgmt Tools, Design Tools, Databases

Handbooks, Standards, Limits

EIA Interim Std 632, IEEE Std P1220, DoD 5000, DSMC Systems Engineering Management Guide, DoD Acquisition Directives,

Metrics and Measures

Adherence to Schedule and Progress Versus Plan
Sub-Process Execution Time And Cost
System Definition Detail
Technical Performance Measurement Resolution

Figure 1. Systems Development and Integration Engineering Template

2. Purpose

The purpose of this document is to define the System Development and Integration Engineering process. This document is intended for use by management and as a training aid for personnel new to the system engineering process.

3. Owner

The owner of this process is 4.1.2.

4. Agents

Agents involved with this process are 4.1.2, other 4.1 elements and appropriate 4.X elements.

5. Preceding processes

Preceding process(es) are those comprising Systems Engineering Management.

6. Inputs and Suppliers

INPUTS	SUPPLIERS
TWP/TBS	(1.0, 4.0)
SEMP	(1.0, 4.1.1)
SEMS/SEDS	(1.0, 4.1.1)
User Needs	(1.0, 4.1.1)
Measures Of Effectiveness, Environments, Constraints	(1.0, 4.10)
Technology Base	(4.x)
Systems Engineering Support	(4.1.x, 4.x)

7. Entry Criteria

ENTRY CRITERIA

- Initiation of a System Development
- Initiation of a System Modification
- Implementation of a Plan for a System Development/Modification
- Approved MNS, TOR/ORD
- Approved Tasking
- Specific Criteria Vary By Acquisition Phase

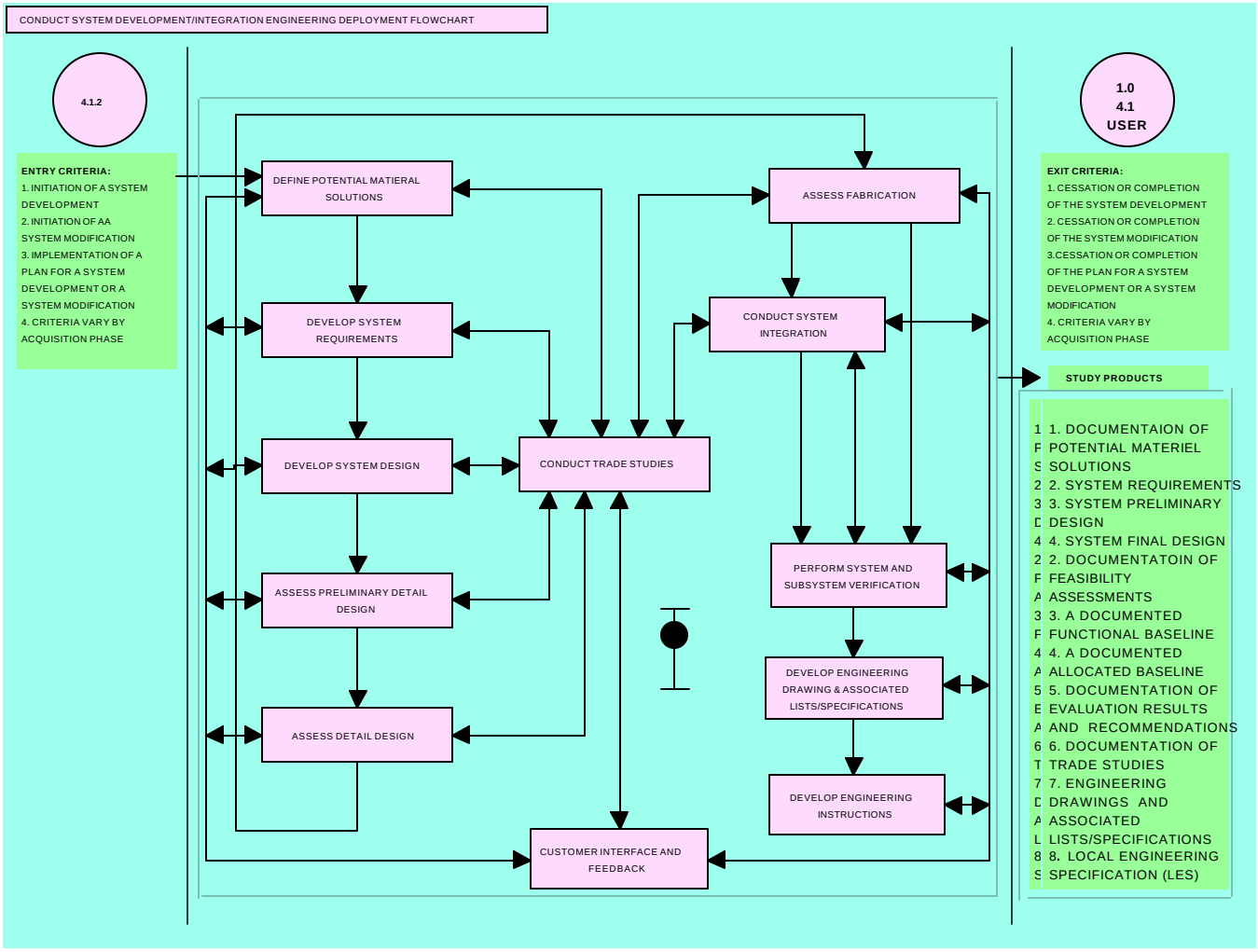
8. Primary Subprocesses

Primary trade study sub-processes are listed below, refer to the deployment flowchart, figure 2 of the 'Overview section, for an illustration of the relationships among the subprocesses.

- Define Potential Materiel Solutions
- Develop System Requirements
- Develop System Design
- Conduct Trades Studies
- Assess Preliminary Detail Design
- Assess Detail Design
- Assess Fabrication
- Conduct System Integration
- Perform System And Subsystem Verification
- Develop Engineering Drawings And Associated Lists/Specifications
- Develop Engineering Instructions
- Customer Interface and Feedback

8.1 Overview

The subprocesses are related as shown in figure 2. Note particularly that trade studies are central to the System Development and Integration Engineering process and that there is feedback to the customer continuously throughout the process. Products are shown as a product of the entire process rather than a product of individual subprocesses. Not illustrated in the employment flowchart is the obvious feedback from review of the study products both by the customer and by management.



Note particularly that trade studies are central to the System Development and Integration Engineering process and that there is feedback to the customer continuously throughout the process.

Figure 2. Systems Development and Integration Engineering Deployment Flowchart.

8.2 Define Potential Materiel Solutions
This subprocess involves analyzing user and customer needs, postulating optional solutions, assessing the feasibility of the solutions and determining measures of effectiveness to judge success.

8.3 Develop System Requirements
This subprocess consists of translating an operational need into system functional and performance requirements, decomposition of these requirements into lower level requirements and definition of a functional baseline.

8.4 Develop System Design
This subporcess consists of developing a design which meets the system requirements.

8.5 Conduct Trades Studies
This subprocess consists of identifying and deciding amongst alternatives associated with the system design or parts of the system design.

8.6 Assess Preliminary Detail Design
This subprocess consists of determining the feasibility of the preliminary system design, identifying high-risk areas and assuring that the design meets all requirements.

8.7 Assess Detail Design
This subprocess consists of determining the feasibility of the detailed or final system design, identifying high-risk areas and assuring that the design meets all requirements.

8.8 Assess Fabrication
This subprocess consists of determining whether system segments or components are being fabricated in accordance with requirements and design and in an acceptable engineering manner.

8.9 Conduct System Integration
This subprocess involves the combining of various system segments, components and subcomponents into higher level assemblies up to the complete system level.

8.10 Perform System And Subsystem Verification
This subprocess consists of assuring that the system and all its component parts are in compliance with requirements and design and that they function as specified.

8.11 Develop Engineering Drawings And Associated Lists/Specifications
This process consists of developing drawings and associated lists and specifications and assuring that they represent the system design and that they can be used for fabrication of additional systems.

8.12 Develop Engineering Instructions
This subprocess consists of development of instructions for manufacturing to assure that the manufacturing process can be efficiently carried out and that there are minimal problems.

8.13 Customer Interface and Feedback
This subprocess consists of assuring that both the user(s) and customer(s) and the developer(s) and agents of these, agree and understand the status, plans, problems, and changes related the development.

9.0 Supporting Subprocesses
Supporting subprocesses include Engineering Support From Other Disciplines, Especially 4.x.1.

9.1 Engineering Support From Other Disciplines
These supporting subprocesses involve those tasks necessary to the system development. The exact definition of these tasks is unique to each system development and will vary for each individual system development.

10. Timeline

There is no one timeline or schedule nor a generic timeline or schedule for a System Development and Integration effort. An indication of where System Development and Integration are performed relative to the acquisition timeline is provided in figure 3. The timeline or schedule is dictated by constraints such as:

- The size and complexity of the system
- The state-of-the-art of the system (i.e., is it pushing the state-of-the-art or is well within the state-of-the-art)
- The formality of the effort
- Time constraints on the effort
- The number of system interfaces
- The developmental state of systems with which the system being developed must interface
- The number of available resources
- Management constraints
- Situational constraints

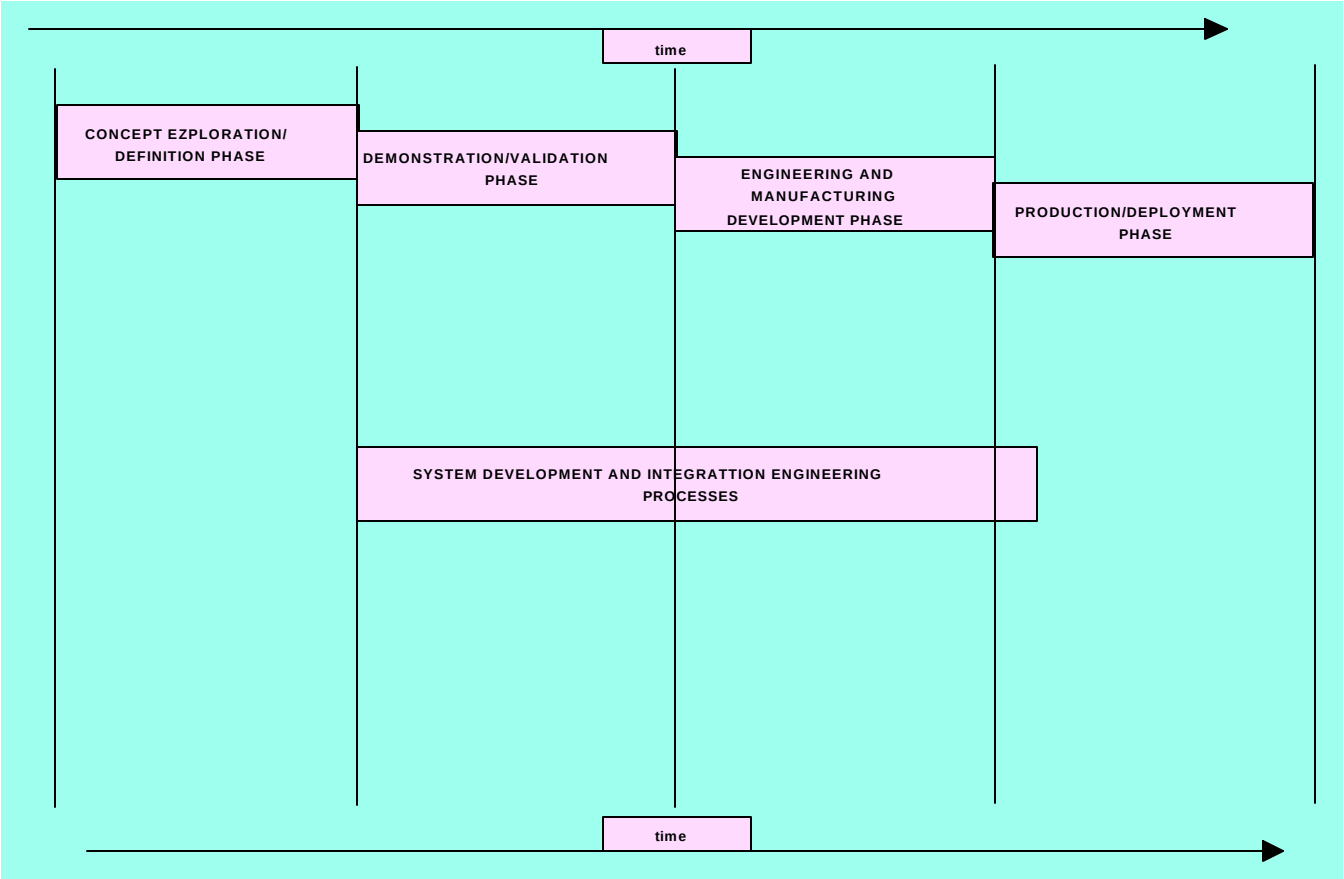

time
CONCEPT EZPLORATION/
DEFINITION PHASE
DEMONSTRATION/VALIDATION
PHASE
ENGINEERING AND
MANUFACTURING
DEVELOPMENT PHASE
PRODUCTION/DEPLOYMENT
PHASE
SYSTEM DEVELOPMENT AND INTEGRATTION ENGINEERING
PROCESSES
time

Figure 3. Systems Development and Integration Engineering processes relationship to Acquisition Timeline.

11. Outputs and Customers

Outputs and customers are:

- Candidate System Concepts, Feasibility Assessments [1.0, User]
- Functional/Allocated Baselines, Functional Partitions, Interfaces, Decision Database, Measured System TPMs [1.0, 4.1, 4.x, 5.0]
- Trade Results, Configuration Recommendations [1.0, 4.1, 4.x]
- Technical Reports, Recommended Baseline Changes, SCNs, ECPs [1.0, 4.1, 4.x, 5.0]
- Engineering Drawings And Associated Documentation [1.0, 4.x, 5.0, OPTEVFOR, User]
- Engineering Instructions [User, 1.0]

12. Exit Criteria

Exit criteria include:

- Cessation or Completion of the System Development
- Cessation or Completion of the System Modification
- Cessation or Completion of the Plan for a system Development or Modification
- Criteria Vary By Acquisition Phase

13. Next Process(es)

The next process or processes could include any of the 4.1 processes, hence the nomenclature ‘multiple processes’.

14. Tools

Use of specific tools cannot be recommended since the selection of tools will sepend on the system , the budget, the user, as well as many other factors unique to each system development. Very often, the tool set will be driven by a development prime or subcontractor selection.

Generic Tools include:

- TPM Tracking Tools
- Requirement Management Tools
- Design Tools
- Databases

15. Process Improvement Metrics and Measures

Process improvement metrics and measures include:

- Adherence to Schedule and Progress Versus Plan
- Sub-Process Execution Time And Cost
- System Definition Detail
- Technical Performance Measurement Resolution

Processes can be judged to be improving if a quantative improvement can be measured for any or all of the metrics and measures.

16. Standards and Handbooks

- EIA Interim Std 632 (still under development)
- IEEE Std P1220
- MIL-STD-499 (reference)
- Defense Systems Management College Systems Engineering Management Guide (reference)

17. Applicable Training and Experience

Applicable training includes an technical/scientific bachelor of science degree (e.g., electrical engineering) and expertise in the scientific or engineering aspects of the system development. On-the-job training ans experience includes performance of tasks which involved the subject areas of the system development or performance of, or involvement in, performance of a previous system development. Training can also be achieved through study of previously performed system developments and comparison of efforts to the process definition contained in this document. More formal training is available form the Defense Systems Management College in the form of system engineering courses.

18. Reference Material

18.1 General

General references include:

- DoD 5000
- DSMC Systems Engineering Management Guide
- DoD Acquisition Directives

18.2 Example

Since this is a high-level process description, examples will be included in lower-level descriptions.

19. Voice of the Customer

The voice of the customer is the customer or the customer's agent or agents. The voice of the customer is accessed through oral, written, formal, and informal means of contact with the customer or the customer's designated agent or agents. See figure 4 for an explanation of the customer, the development agent, the developer, and the user. The system customer is at the hub of the systems engineering process and the outputs of the process are provided to the customer for his users, see figure 5. The user should always be at the hub, as portrayed in figure 5, as well as the system customer.

SYSTEM CUSTOMER(S)	The system customer is the organization which has initiated the system development. For example a PMA who desires procurement a new mission planning system initiates such a system development.
DEVELOPMENT AGENT	The development agent is the technical organization who plans and oversees the development. For example, the development agent may be NAWCAD who reports directly to the PMA.
PROCESS CUSTOMER(S)	The process customers are suborganizations within the development agency. For example, 4.1.1. may be a process customer.
DEVELOPER	The developer is the organization actually doing the development. For example, this organization may be the the development agent or it may be a prime contractor.
USER(S)	The user is the organization which will use the system. The user may or may not be the customer.

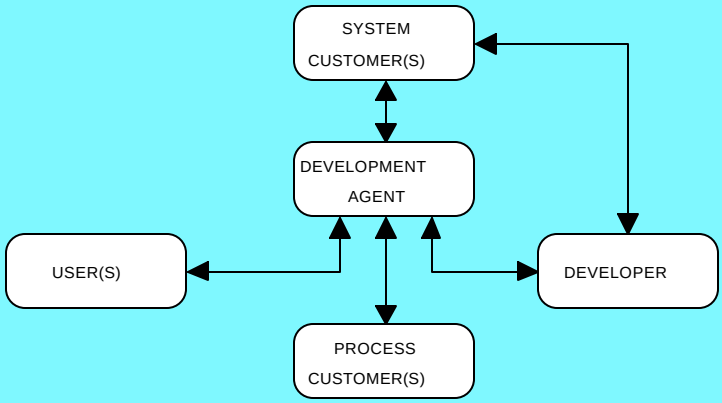


Figure 4. Definition of the customer, the development agent, the developer, and the user.

SYSTEMS ENGINEERING IS AN INTERDISCIPLINARY APPROACH TO EVOLVE AND VERIFY AN INTEGRATED AND LIFE-CYCLE BALANCED SE
SYSTEM PRODUCT AND PROCESS SOLUTIONS **THAT SATISFY CUSTOMER NEEDS**

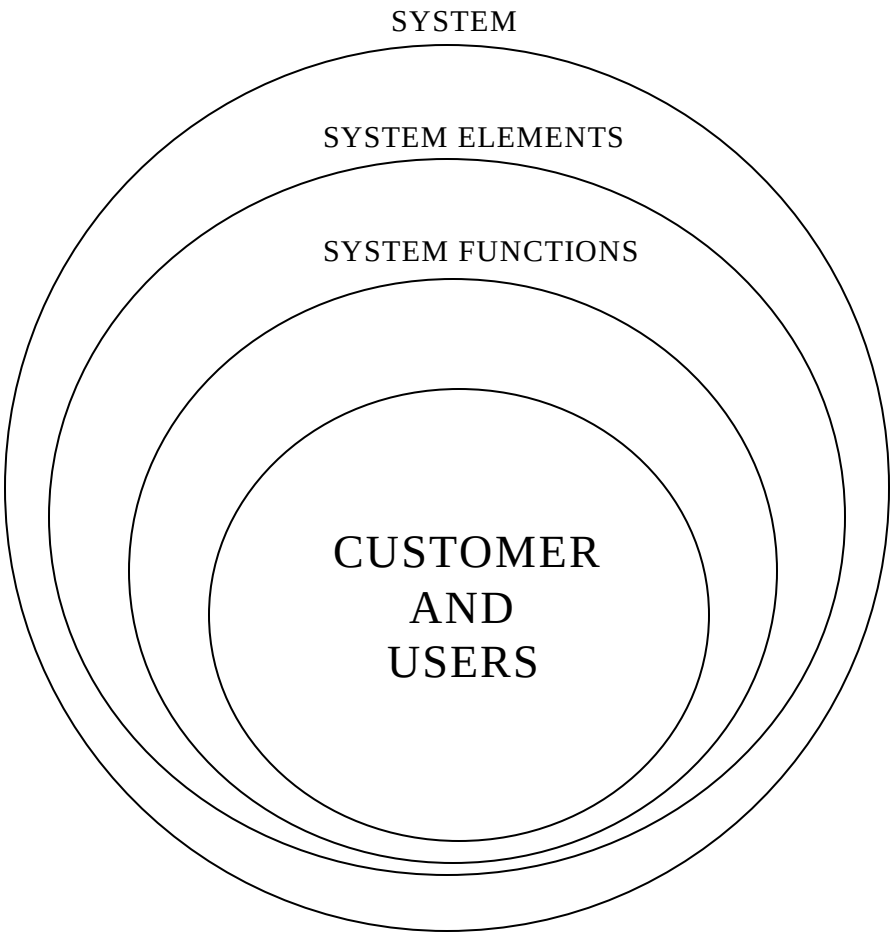


Figure 5. System/customer/user/output relationship.

20. Voice of the Process

The voice of the process is the system development lead or his designated agent or agents. The system development lead communicates with the development and integration team and the customer or the customer's agent(s) through oral written, formal, and informal means. See figure 5.

21. Detailed Process Description

21.1 Define Potential Materiel Solutions

This subprocess involves analyzing user and customer needs, postulating optional solutions, assessing the feasibility of the solutions and determining measures of effectiveness to judge success. This may include:

- Assessment of the ability of existing systems to use user/customer needs
- Assessment of the ability of modifications to existing systems to meet needs
- Identification of all options from combining, modifying existing systems to development of new systems
- Assessment of the risks associated with each alternative and risk abatement plans
- Recommendations to the user/customer and appropriate supporting analyses and data
- Interface with the customer/user
- Developing/reviewing documentation
- Presentation of results

21.2 Develop System Requirements

This subprocess consists of translating an operational need into system functional and performance requirements, decomposition of these requirements into lower level requirements and definition of a functional baseline. This includes:

- Examination of alternative requirements structurings
- Examination of alternative requirements allocations
- Identification of the development paradigm to be used (i.e., waterfall, spiral, et al)
- Identification of alternative functional baselines
- Tracing operational requirements/user and/or customer needs into the system requirements
- Assuring that system requirements are independent of design, unless required
- Assuring that each requirement has the following main attributes:
  - Complete
  - Concise
  - Testable
  - Traceable
- Identifying additional requirement attributes which may be unique to the development effort
- Interface with the customer/user
- Recommendations for the requirements structuring, allocation, functional baseline, and/or the development paradigm
- Developing/reviewing documentation
- Presentation of results

21.3 Develop System Design

This subporcess consists of developing a design which meets the system requirements. Design development includes:

- Identification of alternative designs and assessments of their risk
- Design simulation
- Trade studies to examine candidate designs
- Design feasibility and risks
- Tracing requirements into each design alternative
- Assuring that planned interfaces to other systems are acceptable from all aspects including security
- Recommendations for the design approach with supporting analyses and data
- Identification of high risk areas within the selected design
- Interface with the customer/user
- Developing/reviewing documentation
- Presentation of results

21.4 Conduct Trades Studies

This subprocess consists of identifying and deciding amongst alternatives associated with the system design or parts of the system design. This includes performance of any or all of the following trade study subprocess as defined in the Trade Studies Process Document:

- Analyze Tasking and define Trade Off Problem
- Define Study Objectives, Requirements, Constraints, and Assumptions
- Identify, Analyze and Evaluate Trade Off Study Approaches
- Define Trade Study Team
- Develop Trade Study Plan
- Identify Alternatives
- Formulate Selection Criteria
- Weight The Criteria
- Define Formats to Illustrate Comparisons
- Evaluate Alternatives
- Perform Sensitivity Analysis on Alternatives
- Prepare Trade Study Report with Impacts
- Prepare Risk Template: Trade Studies
- Interface with the customer/user
- Developing/reviewing documentation
- Presentation of results

21.5 Assess Preliminary Detail Design

This subprocess consists of determining the feasibility of the preliminary system design, identifying high-risk areas and assuring that the design meets all requirements. This includes:

- Development of 'scenarios' with which to test/assess the design
- Design simulation
- Preparation of 'storyboards' depicting system operation
- Instituting a user survey
- Tracing requirements into the design
- Performing additional design feasibility studies
- Interface with the customer/user
- Developing/reviewing documentation
- Presentation of results

21.6 Assess Detail Design

This subprocess consists of determining the feasibility of the detailed or final system design, identifying high-risk areas and assuring that the design meets all requirements. This includes:

- Development of 'scenarios' with which to test/assess the design
- Design simulation
- Preparation of 'storyboards' depicting system operation
- Instituting a user survey
- Tracing requirements into the design
- Performing additional design feasibility studies
- Interface with the customer/user
- Developing/reviewing documentation
- Presentation of results

21.7 Assess Fabrication

This subprocess consists of determining whether system segments or components are being fabricated in accordance with requirements and design and in an acceptable engineering manner. This includes:

- Performance of quality assurance tests or reviews
- Assessment of compliance of the fabrication process to plans and specifications
- Identifying areas for improvement of the process or overall efficiency
- Assessing the engineering acceptability of the processes and plans
- Revising or making recommendations for revising plans and/or processes
- Assess the transferrability of the processes to large scale production, if applicable
- Interface with the customer/user
- Developing/reviewing documentation

- Presentation of results

21.8 Conduct System Integration

This subprocess involves the combining of various system segments, components and subcomponents into higher level assemblies up to the complete system level. This includes:

- Assessment of the overall integration process
- System integration test development and performance
- Perform a user/customer evaluation of the integrated system
- Prepare recommendations to user/customer
- Interface with the customer/user
- Developing/reviewing documentation
- Presentation of results

21.9 Perform System And Subsystem Verification

This subprocess consists of assuring that the system and all its component parts are in compliance with requirements and design and that they function as specified. This includes:

- Performing user/customer evaluations
- Verifying system requirements are met, the design is as specified, and that system documentation is acceptable
- Performing system stress testing
- Interface with the customer/user
- Developing/reviewing documentation
- Presentation of results

21.10 Develop Engineering Drawings And Associated Lists/Specifications

This process consists of developing drawings and associated lists and specifications and assuring that they represent the system design and that they can be used for fabrication of additional systems. This includes:

- Reviewing drawings for accuracy
- Assuring the completeness of the drawing set
- Assuring reproducibility of original drawings
- Assessing the drawings, lists and specifications for understandability
- Making recommendations to the user/customer
- Interface with the customer/user
- Developing/reviewing documentation
- Presentation of results

21.11 Develop Engineering Instructions

This subprocess consists of development of instructions for manufacturing to assure that the manufacturing process can be efficiently carried out and that there are minimal problems.

- Reviewing instructions for accuracy
- Assuring the completeness of instructions
- Assuring reproducibility of originals
- Assessing the instructions for understandability
- Making recommendations to the user/customer
- Interface with the customer/user
- Developing/reviewing documentation
- Presentation of results

21.12 Customer Interface and Feedback

This subprocess consists of assuring that both the user(s) and customer(s) and the developer(s) and agents of these, agree and understand the status, plans, problems, and changes related the development.
This includes:

- Oral, written, formal and informal communications with the user/customer
- Keeping the customer and management totally and honestly informed during the entire course of the development
- Assuring user/customer needs and desires are reflected in the system development

- Assuring the system meets user/customer needs and that the user/customer are satisfied with all aspects of the development up to the final product

22. Expert Advice

- Recognize tacit assumptions
- Consider subsequent steps in a development while performing a current step or phase (e.g., consider fabrication during the design stages)
- Utilize past development efforts for reference and ideas
- Resist skipping steps for the sake of time/schedule
- Include all customers and users in the process
- Strive for completeness at every stage, do not consider earyl process stages ‘high level’
- Do keep the customer and management totally and honestly informed during the entire course of the trade study
- Do keep the customer and management totally and honestly informed during the entire course of the development, this can done through periodic briefings
- Do keep a notebook such as an Engineer's note book from the very beginning of the development until termination. Potential benefits of a notebook include:
  - Patent rights
  - Applications to future developments
  - Justification for actions taken
  - Information for anyone who joins the project
  - General future reference

  Document at least the following:
  - Instructions
  - Dates
  - findings
  - Decisions, new or revised orders and changes in direction
  - Reasons
  - Team changes such as numbers and turnover
  - Conclusions
  - Changes in any of the above
- Do maintain configuration control on all appropriate aspects of the development
- Do pay special attention to interfaces, both physical and functional, and their control
- Do not use new technology unless it is assessed with trade studies
- Do not put documentation off and attempt to do it ‘later’
- Ensure that all formal documentation is quality controlled
- Retain all solutions "eliminated" through in order to revert back to a previous point in the development or to reconsider them at a later date

23 Lessons Learned

- Consider all alternatives during every process; if this is not done, the development may not provide the most efficient or optimal solution.
- Fully validate new technology prior to attempted use in any part of a system
- Do what is right, not what is expedient
- Never ‘hide’ things, communicate both good and bad news
- Maintain a high, continuous level of communication with the user/customer
- Solicit users/customers for level of satisfaction throughout the development
- Developments which involve constraints for some reason may be already aiming at a desired solution rather than being unbiased
- Anticipate questions and prepare answers beforehand; this includes 'what if' questions

24. Points of Contact

The point of contact concerning this document is:

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